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WL-TR-95-2124

SHORT-TERM PROPULSION AND POWER
DEVELOPMENT ANALYSIS/ASSESSMENT AND
INFORMATION DISSEMINATION-(UTC)



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JUNE 1995

FINAL REPORT FOR 07/20/90-06/17/95

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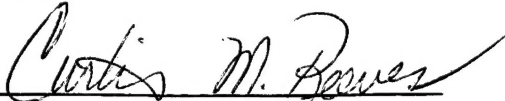
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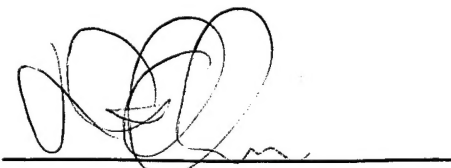
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13. ABSTRACT (Maximum 200 words) This final report documents a summary of all technical accomplishments in performance of the contract "Short-Term Propulsion & Power Development analysis/Assessment and information Dissemination" (Contract F33615-90-C-2031) in support of the Aero Propulsion and power Directorate, Wright Laboratory, Air Force Materiel Command, Wright-Patterson AFB OH. Work accomplished under this contract was documented by Universal Technology Corporation (UTC) as Project S-477. Individual tasks were identified as Project S477-01 through Project S477-50. The various tasks accomplished under this contract covered a wide variety of technical fields and areas of study. Examples include polymer battery research, analysis of the operation of the Compressor Research Facility, an assessment of the integrated High Performance Turbine Engine Technology (IHPTET) Program a drag analysis of a variable flow ducted rocket (VFDR) using the Aerodynamic Preliminary Analysis System (APAS) computer codes, evaluation of Russian scramjet technology and test facilities, test and data reduction procedures for single tube MCH endothermic heat exchanger experiments, generation of residual stress in fan blades using the laser shock peening proceso, on-site support for the biannual IHPTET Steering committee meetings, the biennial Turbine Engine Technology Symposium, analyses on combined cycle engines, NASP flowpath thermal loads and single crystal sheet material for high temperature environments.				
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INTRODUCTION

This final report summarizes the work performed by Universal Technology Corporation (UTC) toward achieving the objectives of Contract F33615-90-C-2031, Short Term Gas Turbine Propulsion Analysis and Assessment. Of the fifty tasks that were identified, forty-seven were funded and accomplished. Status reports were submitted at monthly intervals in accordance with the requirements of the contract. Detailed reports or memoranda were generated and submitted individually for each funded task. The period of performance for this contract was from 20 July 1990 to 19 July 1995.

OBJECTIVE

The objective of this contract was to provide short-term analyses, assessments and lectures/workshops in support of WL/POMXexploratory and advanced development programs with the purpose of providing Air Force program management maximum visibility of the overall program direction, requirements and advancements. Detailed objectives for each task are listed in the paragraphs describing the individual tasks below.

1.0 Task 1 - Air Standardization Coordination Committee (ASCC) WP15 Meeting.

The objective of this task was to plan and support the ASCC WP15 Meeting held in San Antonio, TX, September 1990.

The ASCC meeting was held at the Holiday Inn Riverwalk in San Antonio, TX. There were 29 attendees representing five countries. The meeting contact was Mr. Chuck Delany from Wright-Patterson AFB. The meeting required no on-site support from UTC, no registration fee was charged and two computers and one printer were rented on-site for the duration of the meeting. There were also extensive copying needs that were sent out locally. In a post-meeting follow-up telephone call with Mr. Delany, he concluded that the meeting was a success.

2.0 Task 2 - Variable Format Data Display.

The objective of this task was to establish the capability to maximize understanding and advocacy of APPD R&D technologies through the use of standard/novel electronic display devices and techniques.

As of September 1991, all of the authorized equipment was delivered to the Government satisfactorily completing the task requirements.

3.0 Task 3 - Aerospace Power Technology Information Display.

The objective of this task was to develop and fabricate an informational display of advanced aerospace power technology developments.

All panels, hardware, equipment and signage required under the task were developed/procured and delivered to the satisfaction of the Government.

4.0 Task 4 - Level III Management Meeting on Aero Propulsion and Power Between the U.S. and France: 6 and 7 November 1990.

The objective of this task was to support the subject meeting including setups, historical documentation.

The above-referenced meeting was held in the Building 18 Conference Room at Wright-Patterson AFB in Dayton, OH. There were 16 attendees on the 6th of November and 17 attendees on the 7th of November with a number of them representing France. The meeting required intermittent on-site support from UTC and no registration fee was charged. In a post-meeting follow-up telephone call with Mr. Reeves, he concluded that the meeting was a success.

5.0 Task 5 - Translation of Document #1 From German to English.

The objective of this task was to perform translation of a government furnished document entitled: *Flame Stabilization in a Ramjet Combustor* from the German language to the English language.

UTC, via a sub-contract with the University of Dayton Research Institute, accomplished the appropriate translation of the Government furnished document No. D.L.R. -FB-77-54. Periodic direct dialogue took place between the individual translator and the AF Technical Monitor to insure maximum understanding and satisfaction. This task was successfully concluded in April 1991.

6.0 Task 6 - Advanced Propulsion Analysis Information Dissemination Support.

The objective of this task was to provide short response time support to facilitate information dissemination of government provided draft document.

The Government provided to UTC the (approximately 95-100 substantially handwritten pages) rough draft report "Computer Program to Determine Performance of Augmented Ramjets Formulation Report and User Guide. UTC formatted, typed, prepared graphics and proofread an initial draft of a camera ready document suitable for printing by the Government. This initial draft was delivered 29 Mar 91 to the Government for their review and comments. The Government's review comments were incorporated into a final camera-ready document.

7.0 Task 7 - Flight Dynamics Directorate Industry Days Symposium.

The objective of this task was to provide supplementary technical and planning support for the Flight Dynamics Directorate's (FDD) Industry Days activities held 30 April and 1 May 1991 at the Dayton Convention Center.

The primary focus for this task was support of Flight Dynamics Directorate initiatives for technology transfer and strengthening of the aerospace industrial base. Success of this important event required well-managed conference support, high quality visual aids and effective publications and printed materials.

8.0 Task 8 - Aviation Turbine Fuel Technology Symposium Operation.

This task was not funded and no work was accomplished.

9.0 Task 9 - Aerospace Power Technology Informational Videotape.

The objective of this task was to produce a videotape to promote and educate the viewer to the attributes and accomplishments of the Aerospace Power Division.

The informational videotape was fully assembled and completed during May, 1991. This included shooting laboratory scenes, gathering file tape from Contractors and final editing. The informational videotape was delivered on schedule.

Subsequently, an additional requirement (Task 9A) was received. The required revisions to both the narration and visual portion of the videotape were accomplished. The master tape was provided to the Government for reproduction purposes.

10.0 Task 10 - Aerospace Power Technology Presentation Aids.

The objective of this task was the production of high resolution, color presentation/visual aids in situations where short suspense turnaround times are imposed.

Many high quality color presentation/visual aids were developed and furnished to the Aerospace Power Division on a priority, rapid turn-around basis.

11.0 Task 11 - Aerodynamics Preliminary Analysis System (APAS) Computer Code Support.

The objective of this task was to convert APAS code to -386 PC compatibility from VAX version.

A summation of the accomplishments under this task were set forth to WL/POP in a document entitled APAS MEMO. While significant progress was accomplished, further technical effort ceased under this task due to the non-availability of additional funding support.

12.0 Task 12 - Vehicle Integrated Thermal Management.

The objective of this task was to provide technical support and analysis capability in the area of thermal management.

The technical portion of this task was subcontracted with Science Applications International Corporation (SAIC) on 30 Jul 91.

On 23 March, SAIC briefed the Government on the "Vehicle Integrated Thermal Management Analysis Code" (VITMAC) - Phase I Progress. The VITMAC Phase I effort was completed with the inclusion of a User's Manual, A Theory Manual and Software Design Specification. SAIC's Technical Report, dated 9 April 92 was submitted to WL/POPS.

13.0 Task 13 - Support for the Development of Technology Plans.

The objective of this task was to update current and future programmatic issues relating to the Aero Propulsion and Power Directorate (APPD) technical plans.

Between October 1991 and June 1992, UTC provided camera ready materials in support of the FY92 Aero Propulsion and Power Technology Area Plan and provided visual aids in support of briefings to higher headquarters and operational commands. In addition, graphics efforts were accomplished over the weekend preceding the Wright Laboratory Spring Review.

14.0 Task 14 - Polymer Battery Research Initiative Analysis.

The objective of this task was to analyze existing polymer battery research and develop an in-house research proposal initiative briefing.

The effort under this task was completed with a draft presentation briefing submitted to WL/POOS-2, Dr. Larry Scalon.

15.0 Task 15 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct technical analyses and assessments of advanced turbine engine components and the related technologies to provide an independent assessment for the Turbine Engine Division R&D program and to facilitate the transfer of Integrated High Performance Turbine Engine Technology (IHPTET) to full scale development programs.

In response to direction from Dr Donald Dix of the Office of the Deputy Undersecretary of Defense for Research and Advanced Technology, a method of portraying IHPTET accomplishments was developed. Data displays that progress of all three engine classes against their respective Phase I, II and III goals were compiled and submitted in time for the 1992 IHPTET Steering Group Meeting. Effort began to develop the format and make preliminary preparations for the 1992 IHPTET

Symposium. Support was provided for the Tri-Service, NASA, Seven Contractor meeting held to convey need for participation in the 1992 TET Symposium. Other elements of the Symposium were developed including the Brochure, the pre-mailer, and arrangements for the Keynote and Banquet Speakers. A panel of nationally recognized experts in the area of gas turbine engine testing was assembled to analyze the Turbine Engine Division's Compressor Research Facility, to assess alternative strategies for operation and to estimate the resources required for the various modes of operation.

16.0 Task 16 - Assessment and Support for Advanced Turbine Fuel and Lubricant Development.

This task was not funded and no work was accomplished.

17.0 Task 17 - Aerospace Power Technology Informational Display Modification and Display Boards.

The objective of this task was to develop and fabricate informational display boards of advanced aerospace power technology developments to be used with existing display hardware.

UTC researched, designed, fabricated and assembled informational display boards of Air Force and Strategic Defense Initiatives. This effort included photographs and descriptive signs associated with hardware items.

18.0 Task 18 - Aero Propulsion and Power Directorate 75th Anniversary Videotape.

The objective of this task was to produce a videotape to showcase the history and accomplishments of the Aero Propulsion and Power Directorate.

The task included reviewing the following literature: Engineering History 1917-1978: McCook Field to the Aeronautical Systems Division (Fourth Edition), From Huffman Prairie to the Moon, The Memoirs of Ernest C. Simpson, The Heritage of the Flight Dynamics Laboratory, An Encounter Between the Jet Engine Inventors, 2750th ABW Oral History Program: Interview #5 Daniel Adam Dickey, 1917-1967 60th Anniversary: A Pictorial Review - Wright-Patterson AFB, Celebration of the Golden Anniversary of Jet Powered Flight 1939-1989, Tenth Anniversary Historical Symposium, A Little Journey to the Home of the Engineering Division Army Air Service: McCook Field - Dayton, Ohio.

Also, this effort involved numerous coordination and planning meetings with WL/POM representatives and included the development storyboards to tie the words and available early photos together to create an introduction and story that gives a sense of time, place, purpose, etc.

The video was delivered on time and was first used by the Aero Propulsion and Power Directorate during their annual award banquet and subsequently for VIP video and new employee indoctrination.

A report entitled: Research of Aero Propulsion and Power Directorate History and Lineage was delivered to WL/POM.

19.0 Task 19 - Sterolithographic Scaled Physical Model of an IHPTET Engine (Stage 1).

The objective of this task was to initiate effort to develop and fabricate a scaled physical (cutaway) model of an IHPTET engine (Stage 1) incorporating the various components developed by IHPTET contractors.

This effort was subcontracted to UDRI on an incrementally funded basis. The government subsequently chose to discontinue the funding and the effort was not completed.

20.0 Task 20 - Turbine Engine Technology Symposium Operation--FY92.

The objective of this task was to organize and execute all necessary support activities for the successful operation of the 1992 Turbine Engine Technology Symposium to be held 28 September - 1 October 1992 at the Dayton Convention Center (DDC).

This was the primary support task for the 1992 IHPTET Symposium. Efforts included site visits to the Convention and Banquet Centers, coordination of Army and Navy inputs for the Brochure, coordinated printing requirements for the Government Printing Office, development of the banquet video, the Air Force exhibit video, support of the Symposium itself, development of the Proceedings and preparation of a final report.

21.0 Task 21 - Aerospace Power Technology Presentation Aids.

The objective of this task was the production of high resolution, color presentation/visual aides in situations where short suspense turnaround times are imposed.

Numerous viewgraphs, black lines and pictures were accomplished and delivered on a very expeditious schedule.

22.0 Task 22 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct detailed assessments of the IHPTET initiative through: 1) critical path analyses of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics, and

3) evaluation of IHPTET technology transition processes. These assessments were to be delivered in the form of written reports and data including visual aids, video tapes and pictures. The results of this task were to be used in support of two IHPTET Steering Committee Meetings, the 1993 ST Spring Review, the 1993 Turbine Engine Turbopropulsion Planning Review and the 1993 IHPTET Technical Area Status Review.

Effort under this task concentrated on preparation for and support of the IHPTET Steering Committee meeting in Washington in March 1993. A concentrated effort was put forth to update the metric charts which depict IHPTET progress by engine type against the Phase I, II and III goals. In addition, support was provided for a "Tiger Team" charged with the responsibility of analyzing and recommending procedures for optimum support of the five WL/POT research facilities. The outcome of this effort was published in a document entitled, *Strategies for Management of Turbine Engine In-House Facilities*. A briefing was prepared for presentation to the Director of the Turbine Engine Division on 31 March 1993. This meeting generated requirements for several revisions to the plan which were incorporated.

23.0 Task 23 - High Performance Aircraft Design Lecture Support.

The objective of this task was to provide technical and administrative support for the High Performance Aircraft Design lecture.

Appropriate arrangements, including lodging, were made to cover Professor Oleg Samoylovich, Moscow Aviation Institute, Moscow, Russia, and his party on their trip from Ann Arbor, MI, to Dayton, OH, and return. Professor Samoylovich's three-hour lecture was held at the AFIT Auditorium, Building 642, Wright-Patterson AFB, OH, on Friday, 11 December 1992. Approximately 170 persons attended the lecture which was delivered in Russian with English translation. The lecture was videotaped using two separate cameras. The resultant videotapes were burn window dubbed and delivered to Mr. R. Martin at WL/POM.

Two video tapes of the lecture were edited into one consolidated summary tape that was delivered to the government for their utilization.

24.0 Task 24 - Aero Propulsion and Power Directorate Technology and Informational Transfer Support.

The objective of this task was the support of the Directorate's initiatives for technology transition, transfer and strengthening of the aerospace industrial base. This support requirement included research, development of necessary text, photography, sketches and art work associated with a Directorate brochure, video and exhibit.

This task was established to produce a 75th Anniversary Video and Brochure documenting the accomplishments of the Aero Propulsion and Power Directorate since its beginning at McCook Field in 1917. A considerable amount of historic

research and live videography was accomplished to capture the most important achievements in a 27 minute video and 24 page brochure. The video was shown at the APPD annual Heron Award event at Sinclair College auditorium in May 1993.

25.0 Task 25 - Advanced Propulsion Component Technology Assessment and Transfer Support.

The objective of this task was to conduct technical assessments of advanced propulsion components, development and related technologies to provide an independent assessment of the Advanced Propulsion Division's R&D program.

Effort was expended in support of the AGARD Propulsion and Energetics Panel at its meeting in the United States in 1993. In addition, graphics and display boards depicting U.S. and foreign missiles were prepared for display during tours of senior DOD personnel. A review of stored classified material for potential consolidation was accomplished.

26.0 Task 26 - Aerospace Power Technology Presentation Aids and Aerospace Technology Informational Display Board Modification and Repair.

The objective of this task was the production of high resolution, color presentation/visual aides in situations where short suspense turnaround times are imposed. Modify and repair informational display boards used by the Aerospace Power Division.

The informational display boards previously designed and fabricated by UTC were reviewed and inspected with the customer for repairs, modifications and updating as appropriate. The rework efforts were accomplished in a timely manner.

27.0 Task 27 - Preliminary Propulsion/Airframe Integration Assessment of High Speed Airbreathing Propulsion Systems.

The objective of this task was to conduct preliminary propulsion/airframe integration assessments of high speed airbreathing propulsion systems through: 1) aerodynamic modeling of configurations, 2) benchmarking with available test data, 3) archival reviews of application configurations and 4) performance simulations. The assessments will be delivered in the form of written reports, presentations and presentations aids.

During this effort, a drag analysis of Variable Flow Ducted Rocket (VFDR) using Aerodynamic Preliminary Analysis System (APAS) was accomplished, a comparison was made of the VFDR & AAAM (Navy Missile) Aerodynamic Drag and two programs were developed to assist the APAS analysis.

28.0 Task 28 - Design Approaches for Hypersonic Flows Support.

The objective of this task was to provide technical and administrative support for the Design Approaches for Hypersonic Flows lecture.

Various arrangements and activities were consummated to support the visit and lecture by Professor Gorimir G. Chernyi from the Russian Academy of Sciences on 16 and 17 February 1993.

The support activities included, but were not limited to the following: printing, fabricating and delivery of 8 each 24" X 36" posters to announce and advertise the lecture; providing for appropriate airline transportation, per diem, lodging accommodations and necessary local transportation during the official visit. Also provided was a serially numbered, limited edition copy of *"From Huffman Prairie to the Moon"*, personally autographed by the author.

29.0 Task 29 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct detailed assessments of the Integrated High Performance Turbine Engine Technology (IHPTET) Initiative through analysis such as: 1) critical path analysis of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics, and/or 3) evaluation of IHPTET technology transition processes. These assessments will be delivered in the form of written reports and data including visual aids, video tapes and pictures. This effort was the second phase of a three phase yearly program. This task was to support follow-up from the March IHPTET Steering Committee meeting, the IHPTET ATPP meeting, the XT Spring Review and the August 1993 IHPTET document update. This second phase effort was also support planning for the August IHPTET Steering Committee meeting, the DOD S&T review, the Scientific Advisory Board (SAB) review, the FY95 Buy Plan, the February 1994 IHPTET Steering Committee and the IHPTET Planning Document update.

Work under this task commenced with generation of visual aids for the 1993 Spring Review and charts for Dr Don Dix. In addition, a briefing entitled "IHPTET and the New Defense Environment" which summarizes the changing threat, new environment issues/concerns and IHPTET Strategy/Action Plan were developed and integrated. A draft copy of a four page brochure displaying IHPTET Dual-Use technologies was created.

30.0 Task 30 - Combined Cycle Propulsion Component Analysis.

The objective of this task was to perform: 1) On-Site analytical and experimental investigations of combined cycle air breathing engine components including (but not limited to) the following: combustors, nozzles, fuel systems and heat exchangers, 2) Development of computational methods for determining component performance, such as energy balance of catalytic heat exchangers/reactors typical of those proposed for hypersonic propulsion systems.

Under this effort, design studies were conducted, data reduction procedures were developed and overall technical advice for the single tube MCH endothermic heat exchanger experiments conducted in WL/POPT's Room 22 was provided.

Also, work was completed on converting the heat exchanger code to a finite difference form.

31.0 Task 31 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct detailed assessments of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative through analyses such as: 1) critical path analyses of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics and/or 3) evaluation of IHPTET technology transition processes. These assessments will be delivered in the form of written reports and data including visual aids, video tapes and pictures. This effort was the third phase of a three phase yearly program. This task was to support the follow-up from the March IHPTET Steering Committee meeting, the August 1993 IHPTET document update, the August IHPTET Steering Committee meeting, the DOD S&T review and the Scientific Advisory Board (SAB) review. The third phase effort was to also support planning for the ATPP meeting, the FY95 Buy Plan, the February 1994 IHPTET Steering Committee and the February 1994 IHPTET Planning Document Update.

Visual aids, posters and transparencies depicting IHPTET technologies were developed for the ASC Commander, NASA LeRC, the CRF Control Room and the Air Combat Command. Revision of the IHPTET Critical Path Charts was accomplished. Sets of the 1993 Spring Review Charts were produced in 35mm slide format. Preparations for a visit by Dr Anita Jones from the DOD were heavily supported. Work continued on the Dual-Use brochure. On-site support of the August 1993 IHPTET Steering Committee meeting in Alexandria was provided. Several meetings in support of the 1994 IHPTET Symposium were held. Materials from the 1992 brochure were provided to the Naval Air Warfare Center, Aircraft Division, Trenton in digital format for use in preparation of a briefing. Proceedings from the IHPTET Review for the Materials Industry were received from the Government Printing Office.

32.0 Task 32 - Residual Stress Generation by Laser Shock Peening.

The objective of this task was to generate a residual stress in thirteen fan blades by the laser shock process.

UTC, via a subcontract with Wagner Laser Technologies, provided the technical expertise and equipment to accomplish the laser shock peening of thirteen (13) F101 fan blades.

33.0 Task 33 - Residual Stress Measurement of Laser Shock Peened Blades.

The objective of this task was to use x-ray diffraction to measure the residual stress of three laser shock peened blades.

UTC, via a subcontract with Lambda Research, Inc., accomplished the measurement of the residual stress of three (3) laser shot peened F101 fan blades by using x-ray diffraction.

34.0 Task 34 - Air Logistics News Letter.

The objective of this task was to develop an informational newsletter containing advanced turbine engine technology developments.

UTC developed the general format and updated an appropriate mailing list to reach the working level structures personnel within the Air Force engine community. Subsequently, four editions of the newsletter were prepared and delivered to the customer.

35.0 Task 35 - Manufacturing Support for F-22/F119 and IHPTET Demonstrator Engines.

The objective of this task was to provide manufacturing planning and assessments for the F-22 engine, IHPTET demonstration engines and advanced technology component concepts.

Under this task, the F-22/F119 System Program Office was supported on several technical fronts including major efforts on the nickel single crystal sheet, hollow fan blade, titanium shot peening, permanent mold castings, new manufacturing processes utilizing plastics and liquid ceramics and several efforts on affordability. Equally significant were day-to-day materials and processing counsel and contracts with manufacturers and suppliers on matters regarding the F119 engine.

36.0 Task 36 - Support for Development of Propulsion and Power Technology Plans.

The objective of this task was to update current and future programmatic issues relating to the Aero Propulsion and Power Directorate (APPD) technical plans and support short response planning documents/presentations.

Effort in support of a Hq AFMC task and support for the Joint Directors of Laboratories (JDL) Technical Panel for Air Vehicles (TPAV) was provided. Review of the Joint Service Program Plan (JSPP) for the Aero Propulsion Subpanel was accomplished. Meetings were held to coordinate requirements for displays of Aerospace Power and Advanced Propulsion Technology. The Aero Propulsion and Power Technical Area Plan was completed and delivered. Copies were forwarded to DOD per request of the Directorate. Visual aids in a variety of formats were produced for higher Headquarters. An independent review of a ground stall problem on the T-3A aircraft was conducted and documented in a report to the Technical Director of ASC/EN. An analysis of various software packages for creation of the APPD Technology Area Plan (TAP) was accomplished. TAP roadmaps in Excel were set up and data entry accomplished. Assistance was provided in coordination and dissemination of "Deficiency Needs" for concept evaluation throughout WL/PO.

37.0 Task 37 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct detailed assessments of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative through analyses such as: 1) critical path analyses of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics and/or 3) evaluation of IHPTET technology transition processes. These assessments will be delivered in the form of written reports and data including visual aids, video tapes, pictures and display boards. This effort is the first phase of a three phase yearly program. This task will support follow-up from the August IHPTET Steering Committee meeting, the February 1994 IHPTET planning document update and the February 1994 IHPTET Steering Committee meeting. This first phase effort shall also support planning for the DOD S&T review, the Scientific Advisory Board (SAB) review, the FY95 Buy Plan and long lead items for the 1994 IHPTET Symposium.

(NOTE: Includes Pegasus Engineering Services' subcontract for the review and evaluation of IHPTET Advanced Concepts.)

A Tri-Service/Industry meeting was held to prepare participants for the 1994 IHPTET Symposium. An instructional briefing for preparation for the annual update of the IHPTET Metric Progress charts was given. Copies of the briefing was mailed to Component Area Managers in the Army, Navy and NASA. Symposium meetings were held at two week intervals commencing in January 1994. Support for the semi-annual IHPTET Steering Committee meeting was accomplished at the Institute for Defense Analysis in February 1994. Support for the Compressor Research and Turbine Research Facilities. Acquisition of a secure display case for high technology IHPTET engine components was accomplished. Advanced engineering concepts for IHPTET was secured from Pegasus Engineering Co.

38.0 Task 38 - Preliminary Propulsion/Airframe Integration Assessment of High Speed Air Breathing Propulsion Systems.

The objective of this task was to conduct preliminary propulsion/airframe integration assessments of high speed air breathing propulsion systems through: 1) analytical predictions of aerodynamic performance characteristics, 2) validation with available wind tunnel test data, 3) archival assessments of applicable configurations, and 4) vehicle performance simulations. The assessments were to be delivered in the form of written reports, presentations and presentation aids.

A summary of accomplishments under this task is as follows:

- AMRAAM wind tunnel data analysis report - critical in helping us understand missile aerodynamic behavior.

- Report documenting our drag predictions for the Ducted Rocket Engine (DRE) concept - Army Missile Command uncomfortable with their preliminary drag predictions for this relatively complicated missile configuration. Our report provided them a "second opinion" adding confidence to their analysis efforts.
- Two reports documenting our aerodynamic (lift, drag & pitching moment coefficients) prediction capability for the AMRAAM and VFDR configurations - Predictions compared against wind tunnel data - Reports establish our aerodynamic prediction capability for these two missile configurations in the supersonic regime.
- JANNAF Paper summarizing aerodynamic prediction capability for three Air-to-Air missile configurations (AMRAAM, VFDR & AAAM) - Paper presented at the 1993 JANNAF Propulsion meeting in Monterey, California.
- Component level drag comparison report documenting the differences between the 1979 wind tunnel tested VFDR configuration and the latest 1994 configuration - Understanding the drag impact resulting from the evolutionary design process is critical for propulsion performance analysis.

39.0 Task 39 - Single Crystal Sheet Processing and Assessment Program (4 Parts).

The objective of this task was to provide cast single crystal input stock for subsequent rolling operations into thin-sheet configurations followed by technical testing and assessments thereof.

This program explored methods for heat treating and deformation processing of metals and alloys, and producing thin sheets of a single crystal superalloy by conditioning the cast alloy microstructure, pack rolling the alloy and post-rolling heat treatment.

Thin sheets of commercial nickel base superalloys have been used in critical components of advanced propulsion systems. These components demand high stiffness, tensile and creep strength and high cycle fatigue properties at temperatures up to 1800°F. Commercial nickel base superalloys and oxide-dispersion strengthened alloys are quite satisfactory at low and intermediate temperatures, but are generally inadequate for prolonged use at high service temperatures.

This program attempted to reduce these shortcomings by providing a method for producing single crystal superalloys in thin sheet form for use in fabricating components for high temperature applications. Directionally solidified single crystal superalloys of improved compositions exhibited high tensile and creep strength, crack growth resistance and fatigue resistance at the high operating temperatures of gas turbine engines. Thick cast sections of an alloy were repeatedly hot worked to thin sheet. The process was applicable generally to a wide range of nickel base

superalloys for producing single crystal sheets and for controlling the extent of recrystallization in polycrystalline alloys.

The subcontractors selected for this program were:

- PCC for their capability to cast single crystal slabs for rolling.
- Dynamet for their unique ability to roll single crystal nickel base superalloys.
- Allison was invited to participate in the evaluation of this new technology. G.E. and P&W stated that they would follow Allison effort since Allison has a very large technical base in Lamalloy (TM) and thin wall single crystal sheet. Allison is making vanes for G.E. and the augmentor for P&W. Since they are the subcontractor on these key components and have the technical manpower, they were selected.
- Williams International was selected because of their unique ability to accumulate many test hours on new material at a very low cost. The use of non-man-rated engines for test beds for new technology has been well established since 1975. They have the facilities, equipment and trained personnel to determine mechanical properties, perform fabrication tests, heat treat and evaluate the microstructure of the sample single crystal material.

Hot rolled P&W 1480 single crystal sheet material was cast at PCC and rolled at Dynamet. A series of heat treatments were performed to determine whether the material could be restored to the original single crystal cast and heat treated fine gamma prime single crystal microstructure.

Samples of the sheet material were cut from the material furnished. The hot rolled material was solution heat treated at several temperatures ranging from 2000°F to 2340°F. The objective of this heat treatment task was to evaluate the level of re-solutioning of the gamma prime as a function of temperature and to define the temperature where the onset of recrystallization occurs.

Test bars were machined and heat treated to the following conditions:

2150F	solution for 4 hrs, rapid cool to RT, age at 1600F, 32 hrs.
2200F "	"
2250F "	"
2300F "	"
2350F "	"(2150F & 2200F untested bars were recycled through another anneal cycle.)"

These test bars were tested in stress rupture and hot tensile.

Conclusions:

1. The P&W 1480 material which had been hot rolled, was apparently single crystal. The microstructure resembles that which would be expected from single crystal material.
2. The solution anneal cycles from 2000F through 2300F did not alter the microstructure substantially. Twinning in the gamma matrix was seen sporadically in the different samples. The anneal temperature did not seem to be a factor in the twinning.
3. The material solution annealed from 2000F through 2300F had poor stress rupture resistance, coupled with high % elongation. There appeared to be a real trend of a drop in ductility from 120% with the 2150F anneal to a 40% elongation at the 2300F anneal condition.
4. At 2350F, the large irregular gamma went into 100% solution, along with a simultaneous recrystallization of the single crystal material. The gamma prime precipitant was of excellent size and shape for good stress rupture properties. However, the recrystallization process left weak grain boundaries with resulting poor stress rupture properties.
5. There does not appear to be a window of opportunity to restore the stress rupture properties of the P&W 1480 hot rolled material. The region left to investigate is between 2300F and 2340F, which is negligible, given standard heat treatment furnace temperature tolerances.
6. Tensile strength at 1200F for the 2350F SA + age material was very high. The property dropped for material SA at 2300F and 2250F which is consistent with the microstructural differences. The 2350F SA dissolved all the blocky gamma, whereas 2300F and below SA material dissolved little of the blocky gamma. The ductility was poor for all the above conditions, but might be improved by some over-aging or other mechanisms. The 2350F SA material would be terrible for creep-limited applications, but may be very good for applications in the 1200F regions.

40.0 Task 40 - Turbine Engine Component Technology Assessment and Transfer Support.

The objective of this task was to conduct detailed assessments of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative through analysis such as: 1) critical path analyses of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics and/or 3) evaluation of IHPTET technology transition processes. These assessments were delivered in the form of written reports and data including visual aids, video tapes, pictures, exhibits and display boards. This effort was the second phase of a three phase yearly program. This task supported the follow-up from the February 1994 IHPTET Steering Committee meeting, the Steering Committee meeting, the DOD S&T review, the Scientific Advisory Board (SAB) review, the FY95 Buy Plan, IHPTET advanced concepts and the 95 IHPTET Symposium. This second phase effort also

was to support planning for the February 1995 Steering Committee meeting, the 1996 Buy Plan and other such activities as directed by the Government.

A set of visual aids for the IHPTET Symposium Affordability briefing were prepared for delivery to OC-ALC. A draft of a brochure describing the capabilities and characteristics of the Compressor Research Facility was prepared and reviewed with CRF management. Effort to develop the Proceedings for the 1994 IHPTET Symposium was begun. The Turbine Engine Division Director's Spring Review Briefing and the Keynote address from the IHPTET Symposium were transcribed from the video tapes. Emerging Advanced Concepts for IHPTET were developed by independent engine specialists under contract. The results from studies on one level maintenance, affordability and life cycle cost were presented. An engine design of an advanced concepts gas turbine engine was developed using 3-D CAD models. On-site support was provided to the August 1994 IHPTET Steering Committee Meeting. The final draft of the IHPTET "Blue Book" which documents the status of the gas turbine industry on a national level was completed. The final version was submitted to the DOD in July 1994. Emerging Advanced Concepts efforts of several subcontractors for IHPTET continued and the results were communicated to the Air Force by videoconferencing. The IHPTET and Dual-Use Brochures progressed to the point where they were ready for submittal to the Government Printing Office. Support to the DOD for integration of a document entitled "A coordinated DOD/NASA/Industry National Military/Civil Sector Aircraft Gas Turbine Engine Technical Development Approach", as completed, assembled and reviewed by the customer.

41.0 Task 41 - Turbine Engine Technology Symposium Operation-1994.

The objective of this task was to organize and execute all necessary support activities for the successful operation of the Turbine Engine Technology Symposium to be held 3 - 6 October 1994 at the Dayton Convention Center.

This task provided the principal resources for the 1994 IHPTET Symposium. Introductory slides, banquet program and final program were vital elements of this effort. The Symposium was held on 3 - 6 October 1994 with participation up about ten percent from 1992. The entire operation was a great success as evidenced by the after action critique. A comprehensive final report was prepared and submitted to the Government.

42.0 Task 42 - Advanced Propulsion Component Technology Assessment and Transfer Support.

The objective of this task was to conduct technical assessments of development advanced components and the related technologies to provide an independent assessment for the Advanced Propulsion Division R&D program.

Dr. Stull, under contract to UTC, 1) prepared and briefed the status of Hydrocarbon Scramjets to ASC/ENF; 2) discussed foreign hypersonic systems with WL/POPS and delineated key merits and deficiencies; 3) reviewed two Russian reports dealing with hypersonic test facilities and hydrogen combustion with

applications to combustion chambers of different types, discussed the results with WL/POPS and provided comments for their discussions with Russian authors; 4) reviewed two Russian reports on hydrogen fueled scramjet technology and numerical investigations of Scram engines, attended an AGARD Lecture series presented by Russians at the Ohio Aerospace Institute, Cleveland, OH, and discussed results of above reports with the Russian authors; 5) participated on a WL/POP tiger team to develop technology program requirements for Hypersonic Scramjet Propulsion Systems and continued to review Russian Scramjet data and analyze their results.

Mr. Henderson, under contract to UTC, initiated effort on the US/France Data Exchange Agreement meeting targeted for summer of 1995. The meeting is being sponsored by the Advanced Propulsion Division (WL/POP). Mr. Henderson met with Mr. Philippe who is the DEA Project Officer for France on this activity.

43.0 Task 43 - Advanced Propulsion and Power Display.

The objective of this task was to complete the development of the Aero Propulsion and Power Directorate's science and technology (S&T) display area.

L. W. Milby, Inc., under subcontract with UTC, coordinated with the customer the requirements, the proposed design, sketches of this display and color tones. Subsequently, the subcontractor finalized the design, produced and installed a historical exhibit in the Building 18 hallway.

44.0 Task 44 - NASP Flowpath Thermal Loads Definition - Phase 2.

The objective of this task was to evaluate selected NASP engine flowpath thermal loads data from primary inlet, combustor, exhaust nozzle, subelement and integrated engine tests. Define thermal loads maps for the baseline engine flowpath. Assess the status of design methodologies for NASP aerothermal loads prediction and structural design. Recommend actions to strengthen the NASP thermal loads database and design methodologies.

Dr. Robert Bergholz, under contract with UTC, generated draft Report No. WL-TR-095XX entitled: *NASP Flowpath Thermal Loads Definition*.

Significant progress was made in this Hypersonic Thermal Project by identifying and cataloging technical documents and tests with thermal loads data. The information was archived in the Reference and Test Summary Databases created with the Microsoft Access 2.0 and Microsoft Excel 5.0 software packages. Both databases can be used to archive documents and test data from future projects, and they can be easily modified to include new features tailored to the specific needs of other programs.

A prototype spreadsheet-based system was established to import test data from various native files into MS Excel workbook format. The system was demonstrated on the Calspan CUBDAT and Wright Laboratories Mach 6 Tunnel datasets. The system can be expanded to include import options for many other data sources.

Detailed evaluations were made of the JHU/APL and CDE thermal loads data.

Finally, a first attempt was made to estimate the ranges of peak thermal loads for a NASP-type hypersonic inlet. The estimates were drawn from a variety of NASP-related component and subcomponent tests. The results were displayed for each inlet subelement in a single chart.

45.0 Task 45 - Support for the T-3A Aircraft Program Independent Review Team (IRT).

This task was not funded and no work was accomplished.

46.0 Task 46 - Manufacturing Assessment of Advanced Low Cost Turbo Propulsion Concepts.

The objective of this task was to identify the technology, materials and processes, and manufacturing sources to assure low cost processing of advanced turbo propulsion concepts.

The F119 engine has a requirement for a light weight 1st stage fan blade. UTC supported this effort on several fronts:

1. Rolled, Machined, Diffusion Bonded Twisted Blades.
2. Forged, Machined, Diffusion Bonded Twisted Blades.
3. Cast and Machined Blades.

Each process had side issues which required support by UTC:

1. The rolled bar stock hollow fan blades required several process reviews which involved walking the manufacturing process, front to back.
2. The forged stock blade work also included working with the Laser Shock Peening process. This effort is leading to a MANTech Program.
3. The Cast Blade program assessed three different types of cores - steel, ceramic and Ti. This effort led to a Materials/Directorate program and a \$222,000 design program with P&W. P&W will work with UTC and Howmet to assure an integrated Design and Manufacturing Program.

Also, efforts were conducted in support of permanent mold casting of the 4th and 5th stage variable vanes made of Alloy "C." There was excellent progress leading to a bill of materials at a greatly reduced price.

In addition, a small effort was conducted in support of CompGlas® for the 4th and 5th stage compressor shrouds.

A great deal of effort was accomplished in support of establishing a ROBUST manufacturing program on the F110 Blade. A secondary effort was the establishment of MANTech Laser Shot Peening Program for the F110 and F119 engines. The laser shot peening program plus manufacturing changes will increase HCF and LCF life.

A separate program on single crystal sheet (see Single Crystal Sheet Processing and Assessment Program) plus this program looked at an advanced alloy system and its processing. The potential applications include combustors, augmentors, compressor disks and shafts. Work in these areas is continuing, which includes a major program supported by the Navy at CTC, Johnstown, PA. The CTC program is based upon UTC work accomplished under this task.

47.0 Task 47 - Specialized Support for Innovative Structures.

The objective of this task was to explore innovative structures to identify technical barriers and critical technical challenges associated with the Integrated High Performance Turbine Engine Technology (IHPTET) Advanced Concepts.

The objective of this task was to explore innovative structures to identify technical barriers and critical technical challenges associated with IHPTET Advanced Concepts Engines. A team of experienced engine specialists reviewed resources of various history offices, assembled information from other sources and compiled a report for submittal to the Government.

48.0 Task 48 - Residual Stress Generation by Laser Shock Peening.

This task was not funded and no work was accomplished.

49.0 Task 49 - Assessments and Transfer Support of IHPTET Technologies.

The objective of this was to conduct detailed assessments of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative through analyses such as: 1) critical path analyses of government component development plans, 2) evaluation of IHPTET progress relative to documented program metrics, and/or 3) evaluation of IHPTET technology transition processes. These assessments were delivered in the form of written reports and data including visual aids, video tapes, pictures, exhibits and display boards. This task supported follow-up from the August 1994 IHPTET Steering Committee meeting, the February 1995 IHPTET planning document update, the February 1995 IHPTET Steering Committee meeting, the DOD S&T review and IHPTET advanced concepts. This effort also was to support the planning for the Scientific Advisory Board (SAB) review, the FY96 Buy Plan, the August 1995 Steering Committee meeting and other such activities as was directed by the Government.

This task provided support to the Turbine Engine Division for efforts in a broad array of research and development activities. First, work was accomplished on a lessons learned study for engine development. Immediately thereafter, preparations began for the February 1995 IHPTET Steering Committee meeting in Washington. Action items were prepared in real time and released prior to adjournment of the

meeting. In preparation for the meeting, all Component Metric charts were updated as was the IHPTET Steering Committee Points of Contact Book. Materials were developed for the visit by the Scientific Advisory Board to elements of the Aero Propulsion and Power Directorate including the Compressor Aero Research Laboratory, the Combustion Research Facility, the Turbine Research Facility and Structures Engineering. Work was accomplished to finalize arrangements for the 1995 Fall meeting of the AGARD Propulsion Energetics Panel to be held this time in the United States.

50.0 Task 50 - Marketing for Survival Seminar

The objective of this task was to teach S&Es key tools for defining and communicating the value of technologies, facilities and expertise.

UTC contracted with Dr. Gary Lundquist of Market Engineering International who presented five one-day seminars on "Marketing for Survival" at Wright-Patterson AFB. Each one-day seminar lasted eight hours. Dr. Lundquist furnished a master copy of his material and 100 copies of his material were produced and provided to the Government.